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Field-store standards conversion: colour operation of the Mk.2B (C06/508) converter/synchroniser

No. 1972/2

Research Department, Engineering Division
THE BRITISH BROADCASTING CORPORATION

RESEARCH DEPARTMENT

FIELD-STORE STANDARDS CONVERSION: COLOUR OPERATION OF THE MK 2B (C06/508) CONVERTER/SYNCHRONISER

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(EL-60)

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Summary

The report describes the way in which colour television signals are transcoded as part of the standards conversion process. The impairments of colour performance brought about by the standards conversion process are also described, together with methods used to minimise their effects.

Transcoding is not used when the equipment is working as a field-store synchroniser and the report describes the other colour circuits which are used in this role.

1. Introduction

The C06/506 and C06/508 television field-store standards converters used by the BBC* convert between the 625/50 and 525/60 colour or monochrome scanning standards. The earlier C06/506 equipment converts in the direction 525/60 NTSC-to-625/50 PAL, and the C06/508 converter operates in the reverse direction.

Each converter performs two fundamental operations:—

(i) to change the number of television lines in each television field and also to change the number of fields per second; these are basic processes of standards conversion and are discussed in this report only in relation to the colour aspects of the converters.

(ii) to change the system of colour coding; for example, the earlier C06/506 standards converter accepts an input of NTSC colour-coded signals and produces an output of PAL colour-coded signals. This process is known as transcoding and the special kinds of transcoding used in the converters are described in this report.

Fig. 1 illustrates the sequence of these operations.

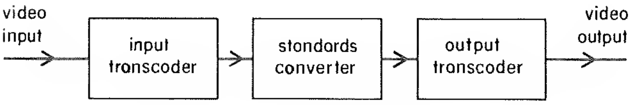


Fig. 1 - The locations of the colour transcoders

* Standards converters of this kind are now being manufactured commercially under licence from the BBC and are being sold to, and used by, a number of other authorities.

The object of this report is to describe the way in which colour television signals are processed to facilitate their passage through the standards converters; some of the detailed reasons behind the choice of colour system are outside the scope of this report and have not been given. For reasons of simplicity, only the colour signal operation of the C06/508 converter is described but the same principle apply to both converters.**

For the purposes of this report, the action of a field-store standards converter[1,2] can be regarded simply as a mechanism for extending or contracting the duration of the blanking interval between successive lines of the television signal. A complete new set of output lines is formed by the converter and the interval between them is made longer or shorter according to the direction of conversion; the actual change depends upon the input and output line frequencies. This effect is particularly important in colour operation because it destroys the coherence of the colour subcarrier between one line and the next.

The interpolation process (whereby all the television lines destined to form the output signal are produced) is another important factor in colour operation because interpolation involves the averaging of colour signals on lines which are adjacent either in space (successive fields) or in time (successive lines of the same field).

The need to transcode[3] has also had an important bearing on the method of colour operation used in the standards converters.

** At the time of writing the performances of the two converters are different in some respects on account of the obsolete v.s.b. r.f. system used in the earlier C06/506 equipment; however, this is now being replaced by a d.s.b. system after which the performance should be similar.

In addition to its use as a standards converter, the C06/508 equipment operates as a 625/50 field-store synchroniser. The colour signal processing for this alternative synchroniser function is discussed separately in the report so that changes in instrumentation, notably the omission of the transcoding equipment in the synchronise mode, and the different signal requirements may be suitably emphasised.

2. Colour signal processing in the standards converter

2.1. General

Transcoding between the input and output standards is an essential part of field-store standards conversion and it was decided that certain advantages could be gained by using a special intermediate colour-coding system within the converter itself. After consideration of many possibilities (including FDM[4] with separate f.m. bands for luminance and colour-difference signals) an Intermediate System was chosen with many similarities to the NTSC system. The colour information is transmitted through the converter, together with the luminance signal, as quadrature amplitude-modulation (q.a.m.) of a colour subcarrier. The frequency of the colour subcarrier is an integral multiple of the input line frequency; this relationship was chosen because of the method of interpolation used. Interpolation is basic to standards conversion and involves averaging the picture information on adjacent lines of both fields and pictures to form the new raster of output lines. Both the chrominance and luminance information is averaged and, to permit this, the phase of the colour subcarrier (for a given hue) must be identical on successive lines, so that it does not affect the adding operation which constitutes the averaging process. These requirements are met by choosing an intermediate subcarrier frequency which is an integral multiple of the input line frequency.

The other considerations governing the choice of frequency are less rigorous. To reduce the effects of 'cross colour' (i.e. the products of the demodulation of high-frequency components within the colour band), the chrominance signal is placed outside the luminance band; thus separation of the chrominance and luminance components of the signal can be effected with bandpass and lowpass filters. The chrominance band must not be placed too high in frequency, principally because of the limited pass-band of the quartz delay lines; nor must the chrominance frequency band be low enough seriously to overlap the luminance band, or mutual interference will occur. Fig. 2 illustrates the colour spectra before, during and after standards conversion; when monochrome signals are being converted the full luminance bandwidth of 4·2 MHz is provided.

Another important advantage of making the subcarrier frequency an integral multiple of line frequency is that the unwanted beats between the NTSC, PAL and intermediate subcarrier produce interference patterns on the output display which are of low visibility. In practice, the beats occur between the colour subcarrier and any residual

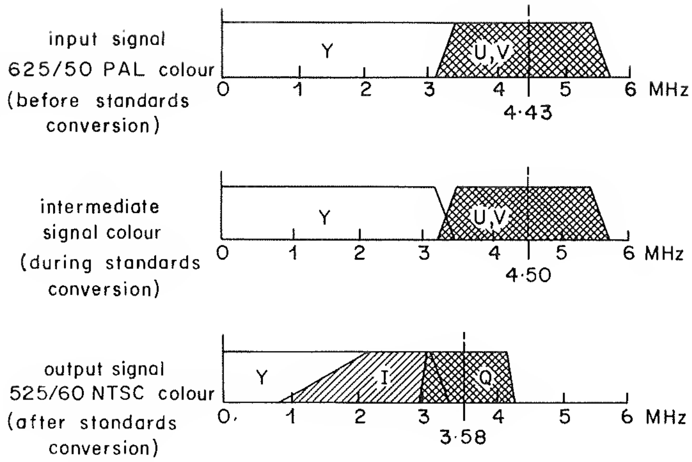


Fig. 2 - Spectra of signals in their passage through the equipment

colour subcarrier(s) remaining from previous transcoding operations. Table 1 below shows the frequency of the beats in relation to line frequency (f_L) and field frequency (f_F)*.

TABLE 1

	NTSC	PAL	Intermediate
NTSC	–	$(n_1+¼)\,f_L+2f_F$	$(n_2+½)\,f_L$
PAL	$(n_1+¼)\,f_L+2f_F$	–	$(n_3+¼)\,f_L-2f_F$
Intermediate	$(n_2+½)\,f_L$	$(n_3+¼)\,f_L-2f_F$	–

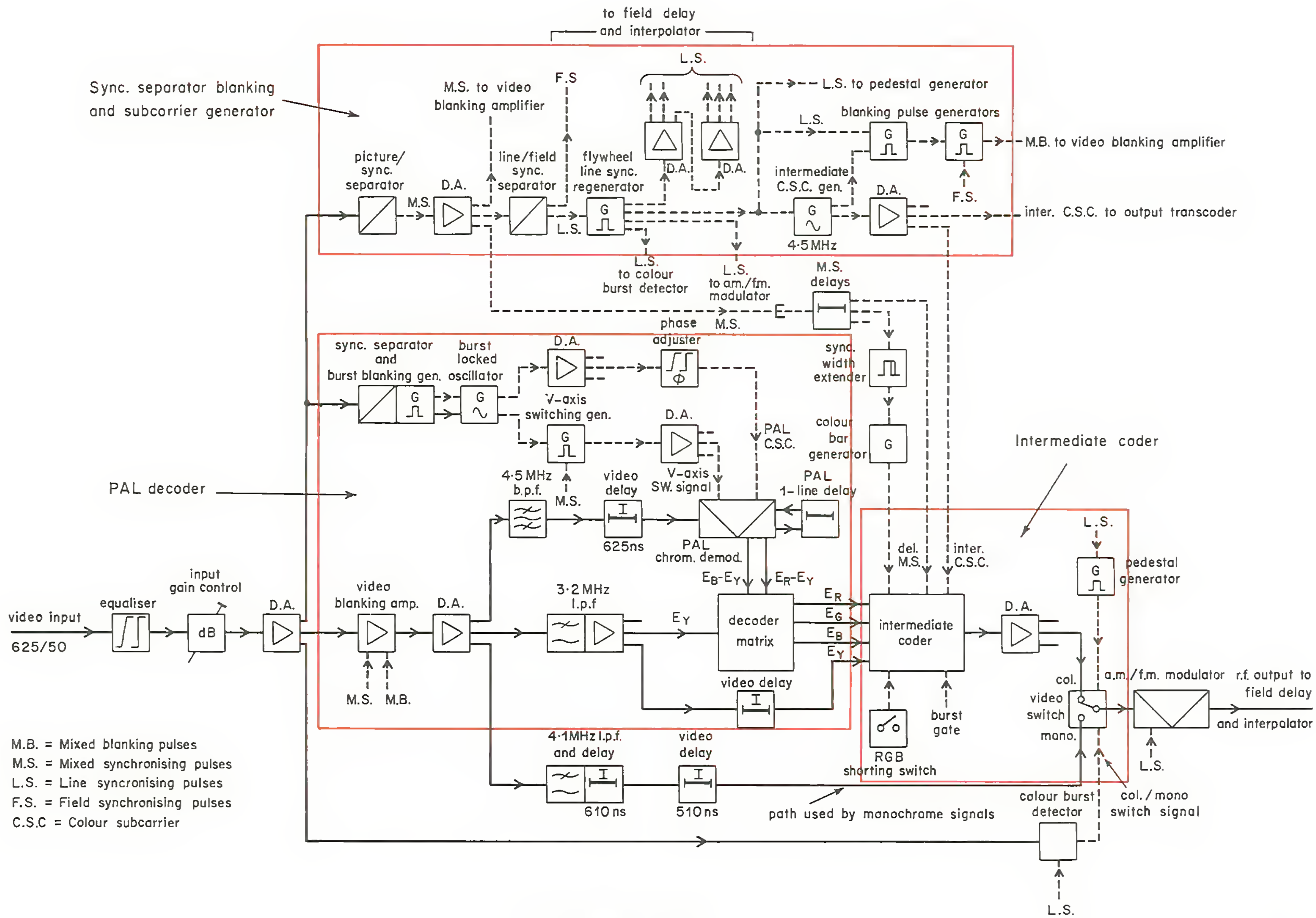
Finally, to improve the signal-to-noise ratio of the timing correction and demodulation proecsses at the output of the converter, a burst is used which is of larger amplitude and of greater duration than a normal burst.

As stated earlier, only the colour signal processing of the 625/50–525/60 (C06/508) converter will be described, but the same principles apply to both converters.

2.2. Input transcoder

The input transcoder can be separated into two main parts. One part processes the video signal, the other generates all the ancilliary signals, e.g. syncs, blanking, etc. which are needed in the transcoder. Fig. 3 is a detailed block diagram of the transcoder; this shows video circuits in heavy lines with the ancilliary signal connections in broken lines.

* n_1, n_2 and n_3 are different whole numbers. This table describes the spatial frequencies of the beats (rather than their actual frequencies which may be changed by standards conversion); either input or output line and field frequencies may be assigned to f_L and f_F to interpret the table in a qualitative manner.



M.B. = Mixed blanking pulses
M.S. = Mixed synchronising pulses
L.S. = Line syncronising pulses
F.S. = Field synchronising pulses
C.S.C = Colour subcarrier

Fig. 3 - Input transcoder

The PAL video input signal is reblanked in preparation for the addition of new burst etc. and the chrominance signal is separated by a bandpass filter. The colour-difference signals are then recovered using a conventional PAL delay line decoder; 'delay-line' decoding is used rather than 'simple' decoding so that the optimum chrominance signal-to-noise ratio is obtained and the differential phase distortion of the input signal is reduced. The luminance signal is derived by passing the incoming video signal through a lowpass filter with a cut-off frequency of 3·2 MHz. The luminance and colour-difference signals are combined in a suitable matrix to form the colour separation signals which are then applied to the inputs of the intermediate signal coder. This is a PAL coder, modified to remove the V-axis switching and to operate at the 4·5 MHz intermediate subcarrier frequency. The coded output signal does not have conventional synchronising pulses added to it; instead, and for reasons given elsewhere[2] a timing 'pedestal' extending from black level to 50% grey level is added, so as to coincide with the burst. This is shown in Fig. 4 from which it will be seen that the use of the pedestal permits the burst to extend from black level to white level; the burst is of 15 cycles duration. The spectrum occupied by the components of the intermediate signal has already been referred to and is shown in Fig. 2.

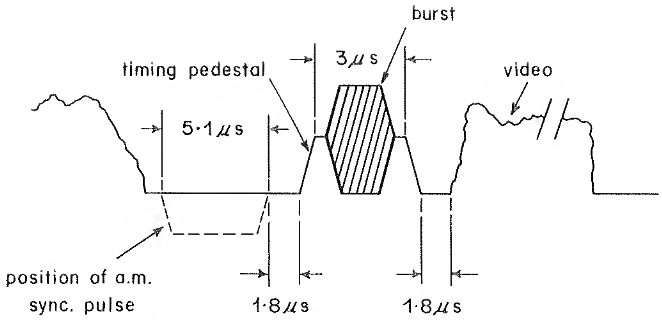


Fig. 4 - Intermediate video signal waveform

The chrominance a.g.c. unit corrects for these variations by measuring the level of each burst and maintaining a suitable setting of gain for the following line. The problems associated with this operation are described later in Section 3.2.

After correction, the signal is demodulated in a conventional way using the local 4·5 MHz subcarrier signal which is locked to station line syncs. The colour-difference signals are matrixed with the reblanked luminance signal to give colour-separation signals, and these in turn feed the NTSC coder to produce the composite, coded NTSC output.

2.3. Output transcoder

The purpose of the output transcoder is to recover the colour information from the intermediate signal and to recode it according to the system required by the output signal standard, i.e. in the case described here, the signal is recoded to 525/60 NTSC.

Fig. 5 is a detailed block diagram of the output transcoder; the signals received by the transcoder have been standards-converted and are thereby correctly timed with respect to the pulses from the local station waveform generator. The upper signal chain shown in Fig. 5 carries luminance signals, the full 4·2 MHz bandwidth* being selected for monochrome signals and 3·5 MHz for the luminance component of colour signals.

The lower chain illustrates the chrominance signal path which is fairly conventional except for the chrominance signal equaliser and the chrominance a.g.c. unit.

The chrominance signal equaliser corrects for static distortions of group delay and amplitude within the chrominance band. It is possible to correct for variations of group delay over the chrominance band up to ±100 ns and amplitune/frequency distortion up to ±3 dB. The effect of asymmetry of the group delay characteristic between the upper and lower sidebands of the chrominance signal is to produce crosstalk when the signal is demodulated and this appears on the picture as spurious colour on colour transitions.

The chrominance a.g.c. unit provides the automatic control which is necessary to reduce the systematic fluctuations in chrominance signal level which occur as the delay lines of the standards converter (which vary in response from one to another) are switched in and out of circuit.

* System M.

3. Instrumental limitations in the colour performance

The principle defects in the colour performance of the equipment are due to defects in the r.f. path of the standards converter and are described in the following subsections.

3.1. Limited r.f. bandwidth within the standards converter

Originally, because of the limited bandwidth of the quartz delay lines it was necessary to use a vestigial-sideband f.m. system[6] to transmit the video information. Improved delay lines and equalisation techniques, however, have sufficiently increased the available bandwidth to allow a double sideband f.m. signal to be used. The earlier (C06/506) equipment still uses a v.s.b. f.m. system, the characteristics of which give rise to differential phase and gain distortions amounting to about 22° and 25% respectively.

The double-sideband system has no such inherent differential phase and gain distortions, although in practice the modulator and demodulator in combination give 5°, and respectively 5% at the normal peak deviation of 1 MHz.

3.2. Quartz delay line equalisation

Both the amplitude/frequency and the group delay/frequency characteristics[7] of the quartz delay lines in the standards converter deviate from the idealised uniform bandpass performance and give rise to differential phase and gain

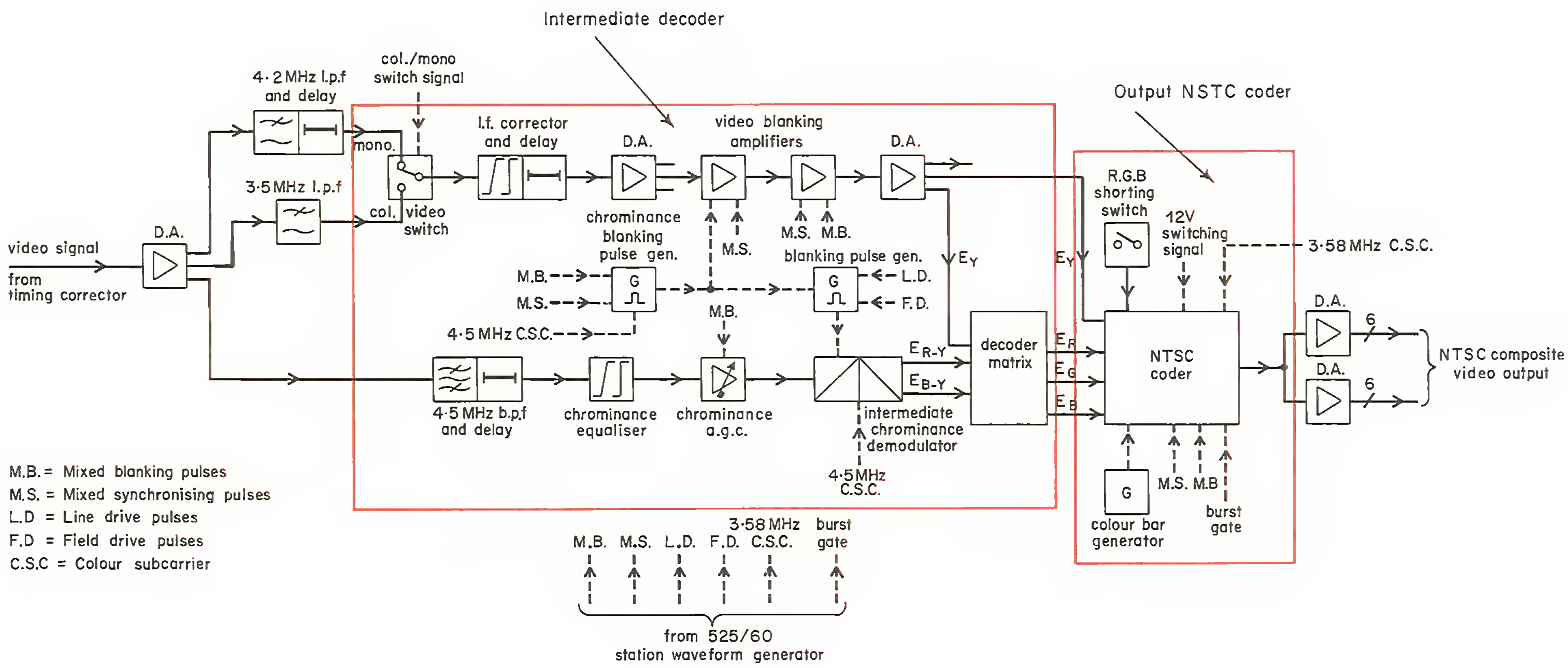


Fig. 5 - Output transcoder

distortions. First, the amplitude/frequency characteristic is not smooth (in practice, equalisation of each delay corrects the response to within only ±¼ dB over the r.f. band (24 – 38 MHz) which means that the amplitude of one chrominance-signal sideband relative to the other may vary significantly when large video excursions occur. Such variations would give rise to both differential gain and differential phase distortion. Second, variations in group delay occur over the equalised frequency band (the maximum permitted variation is 10 ns) and in the worst case about 3 degrees of differential phase and 3% of differential gain distortion could occur within a single delay unit.

In the standards converter, up to 21 delay lines at a time may be connected in series and it might be expected that the overall group delay and amplitude/frequency characteristics of the main store would give much larger overall differential phase and gain distortion; in practice, the individual delay units do not possess similar 'worst case' characteristics and the overall figures are about 5° and 5% respectively. The 21 delay lines are switched systematically through a large number of combinations as the delay within the converter varies; this means that the distortions are also switched resulting in chrominance patterning on the output picture. This patterning is of a regular form, is of fairly low visibility and is not to be confused with the more obtrusive random chrominance 'streaking' which also occurs and which is described in Section 3.5.

3.3. Transcoder imperfections

The principle impairment of the colour signal in the transcoders occurs in the colour decoders. In the coder, the only serious problem is the stability of the carrier-balance, which is affected by temperature and can result in a subcarrier 'leak' of about 1% of peak amplitude; however in the stable environment of a studio centre the effect is not found to be serious.

The main considerations in decoding are:

(a) The axes used for decoding the colour subcarrier should be very close to 90°, otherwise crosstalk will occur between the colour-difference signals. In practice, the axes can be set up to be within 1° of quadrature but thermal effects can cause drifts of as much as 2° to 3° per day.

(b) The colour-difference signal demodulators cause some non-linearity in the decoded colour-difference signal.

(c) Errors can occur in colour balance (differences between the gains of the R, G and B channels); in practice, errors of up to 1% may be present, particularly in the output transcoder where the accuracy of adjustment is impaired by noise on the RGB signals, generated in the converter.

The distortion generated in the remainder of the transcoders are those normally associated with simple units like distribution amplifiers, adders, etc., and are negligibly small.

The undesirable features mentioned above result mainly from design imperfections in the decoder which were of a type intended for monitoring, not for transmission purposes. It was decided that these imperfections were acceptable in the light of other needs; the alternative would have been the development of a new colour decoder.

3.4. Johnson noise

The Johnson noise produced by the equipment arises mainly in the r.f. path and originates in the output pre-amplifier of each quartz delay unit. However, Johnson noise is not the main effect governing the colour performance of the equipment. This is because the signal-to-noise ratio of the head-amplifier in each delay line has a margin of some 12 dB; it is possible to reduce the level of r.f. signal within the converter by some 12 dB before a significant increase in noise can be seen on the output picture. The unweighted luminance signal-to-noise ratio measured with ME1M/504 Noise Meter is 46 dB for the CO6/508 standards converter.

3.5. Spurious signals

Spurious signals are unwanted r.f. signals produced within the delay lines.[7] They are, in general, the summation of a large number of individually small signals which have travelled by other than the prescribed path (and hence have incorrect timing) and which accompany the delayed output signal. Certain forms of spurious signal are more common than others; for example, direct breakthrough to the output of the undelayed input signal and an effect known as the 'Third Time Round' signal are the two important forms. The 'Third Time Round' signal is the reflection that travels from the input transducer to the output, is reflected to the input again and then once more to the output. Because of the large number of spurious signals present in the output, the effect is very similar to that of random noise, although predominant signals can cause moiré patterns on the output picture. This type of interference or noise has the property of being dependent on signal level. The main problem arises because the r.f. sidebands carrying the colour information occur at the edges of the passband of the quartz delays where the levels of spurious signals are highest, which means the greatest interference occurs with the chrominance components. Furthermore, the subjective effect of this is made much more significant because of the high-frequency to low-frequency translation (and hence small- to large-area translation) that occurs in the line-by-line timing correction, gain correction and demodulation of the chrominance signal,[8,9] all of which depend upon the accuracy of burst amplitude and phase. The effect is illustrated in the photograph of Fig. 6 which was taken from a Vectorscope display of the output of the equipment with an applied input signal of 95% saturated colour bars. It can be seen that the spread in the phase and amplitude on the chrominance output signal is about 10°, and 1 dB, respectively.

4. Methods used to minimise the effects of spurious signals

Various practical steps have been taken to reduce the effects of spurious signals on the colour signal. In general, each step has resulted in only a small improvement to the

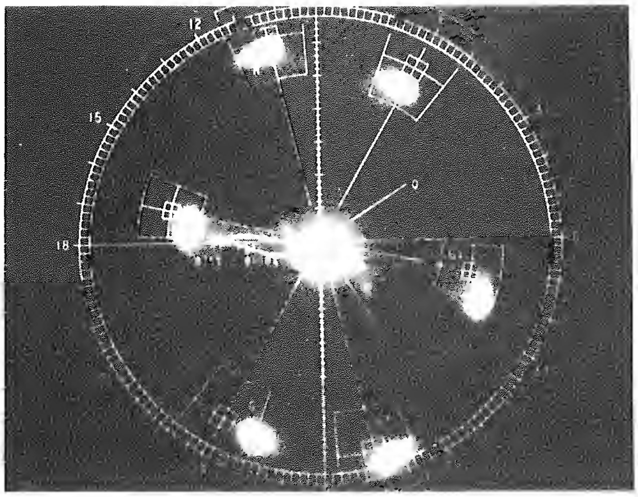


Fig. 6 - Photograph of vectorscope display of colour bars illustrating output chrominance noise

overall chrominance signal-to-noise ratio, but together however, it is estimated that the overall subjective improvement has been equal to one subjective grade. The various steps are described below. Most of them are concerned with obtaining the maximum effective colour-burst signal-to-noise ratio, so as to minimise the line-rate errors in the detection of burst phase and amplitude. No method has yet been devised to reduce the chrominance 'noise' in the active line period. However, in the case of the earlier (C06/506) equipment for NTSC-to-PAL conversion, indeed of the PAL system in general, if the receiver is operating with a PAL delay-line decoder, then a 3 dB improvement in the random noise component of the colour signal is obtained (because of the summation of signals on adjacent lines). There is also some reduction of patterning, characteristic of the main store switching sequence.

In the chrominance Timing Corrector, and the Chrominance A.G.C. unit, both of which utilise the burst, either in phase or amplitude, the maximum possible integration time is used, commensurate with attaining sufficiently fast operation.

It is clearly desirable to generate a burst of long duration (each doubling of the duration of the burst would ideally reduce random noise effects by 3 dB). The duration of the burst is limited by the time available in the line blanking interval and the time devoted to the other essential operations occurring in this interval (e.g. establishing black level). In practice, the burst has a duration of 21 cycles in the earlier C06/506 equipment and 15 cycles in the C06/508 converter. The burst in the latter equipment is shorter because of the need for the post-burst-blanking interval required to allow a fast clamp to operate on the signal after the colour timing correction.

A high-amplitude burst is desirable in order to maximise the ratio of the wanted to unwanted signals and, in practice, the maximum value of burst amplitude, extending from black-level to white-level is used. Unfortunately, the resulting improvement is not as great as expected because the spurious-signal level also increases with burst amplitude.

To accommodate the high-amplitude burst it was necessary to readjust its mean value to mid-grey as distinct from its normal black level value. This high-amplitude burst on a mid-grey 'pedestal' was also beneficial in reducing the effects of differential gain and phase distortions. As described elsewhere[2] the pedestal was also used for synchronising purposes.

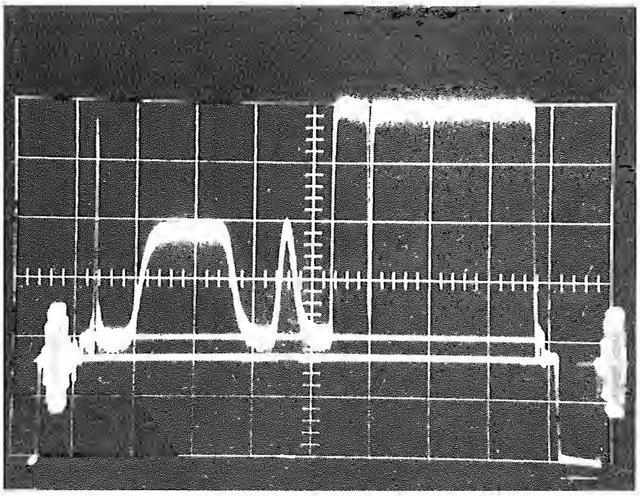


Fig. 7 - Photograph of 2T pulse and bar response of C06/508 standards converter in 'colour' mode

5. Performance measurements

The results of the measurements of performance are shown in the accompanying Table 2 (see p. 10). The pulse-and-bar performance figures were derived using a T unit value appropriate to the NTSC system (i.e. T = 120 ns). This lower value is used because it is bound to apply to the output signal in either direction of conversion; Fig. 7 shows a photograph of the pulse and bar response.

6. Colour signal processing in the field-store synchroniser

6.1. General

For the synchronising process where the input and output colour system is the same (i.e PAL in the case being described) there is no need to transcode and hence there is less impairment of picture quality. Furthermore, by utilising a maximum total delay of one field period within the synchroniser the r.f. path length is kept to an absolute minimum[5] and the distortion within the delay units is thereby reduced. These two restrictions together, however, cause a number of difficulties, two of which affect the processing of colour signals.

(a) Subcarrier phase

To synchronise remotely-generated pictures to a studio, the incoming signal subcarrier must be co-phased with the studio subcarrier. The subcarrier phase varies for eight fields before the cycle is repeated and consequently, as only up to one field of delay is available a method of correcting the subcarrier phase has to be provided. There is a special timing corrector (TC2A) in the synchroniser set aside to do this. and the phase of the output subcarrier is aligned with the local reference, moving the output picture sideways, relative to syncs, by up to ±½ cycle of subcarrier, (or ±113 ns). This enables the synchroniser picture subcarrier to be 'fitted over' the reference picture subcarrier. A consequence of this technique is that the line blanking period may be extended by up to ±113 ns, which, however, lies well within the System I tolerances of ±250 ns for the line blanking period.

(b) V-axis polarity

The use of a total delay of only one field period means that the polarity of the v-axis of the output signal may not be the same as the polarity of the station v-axis reference signal. This condition is detected in a special unit and, should correction be required, the output picture is 'slipped' vertically by one line;[5] this is done by adding or removing a one-line period delay in series with the signal path. This process is bound to succeed since opposite v-axis polarities exist on adjacent lines.

Another parameter of the PAL output signal that may require correction is the 4-field period burst-blanking cycle. Correction is automatic, however, as the incoming bursts are removed from the signal and new bursts are added to the output. The new bursts are generated using the station reference pulses and therefore have the correct 4 field sequence.

6.2. Colour signal processor

The main requirement of the processor is to reblank the signal, add a luminance timing pedestal and a new 'swinging' burst, accurately phased in quadrature on alternate lines. This ensures that the luminance and chrominance timing correctors at the output of the synchroniser operate with signals of maximum signal-to-noise ratio and with a burst of known phase accuracy.

Fig. 8(*a*) and (*b*) is the block diagram of the input and output signal path respectively. The input signal feeds the normal sync separation arrangement and burst-locked oscillator and v-axis switch regenerator. The regenerated v-axis switching signal is used to ensure that the v-axis polarity of the new burst which is generated and added to the video signal is the same as that of the incoming burst.

The PAL video signal is reblanked and a timing pedestal is added. The new burst has maximum amplitude (0·7v p-p) and is developed in the same way as for standards conversion, being added to the timing pedestal. This burst is used by timing correctors 2A and 3 at the output of the equipment as well as to identify the output signal v-axis polarity. Accurate timing correction at the output requires the signal-to-noise ratio of the burst to be a maximum (hence the high amplitude) and that alternate swings of the burst are accurately in quadrature. The PAL burst switcher unit produces these bursts using a continuous subcarrier fed from the burst-locked oscillator. The tolerance of the quadrature phasing has a long term stability of better than ±½ degree.

The reblanked signal with the timing pedestal and new burst passes to the f.m. modulator and thence to the main store.

As in the case of standards conversion, the demodulated chrominance signal suffers variations in amplitude caused by the variable r.f. characteristics of the quartz delay units in the main store and it is necessary to correct these fluctuations. First the low-frequency luminance components of the signal are separated from the high-frequency luminance and chrominance components. This is accomplished without causing impairment using the method shown in Fig. 8(*b*) is used whereby a sine^2 squared low pass filter and subtractor combine to form a high-pass filter. The high-pass filtered signal feeds the chrominance a.g.c. unit in which the chrominance level inaccuracies are adjusted, after which the low frequency components, suitably timed, are added to form the composite video signal (produced by the the PAL burst switch unit driven from station syncs) is added to the output, together with mixed sync pulses to provide a composite PAL output signal.

7. Conclusions

This report describes the colour systems of the Standards Converters and Synchroniser and discusses the colour performance of the equipment. It has shown that the main limitations to the performance are caused by spurious signals generated in the quartz delay lines. It has pointed out the various methods used to optimise the colour performance; if improved means of storing television signals with their enormous information rates, were available, the principal defect of the converters and synchroniser could be removed.

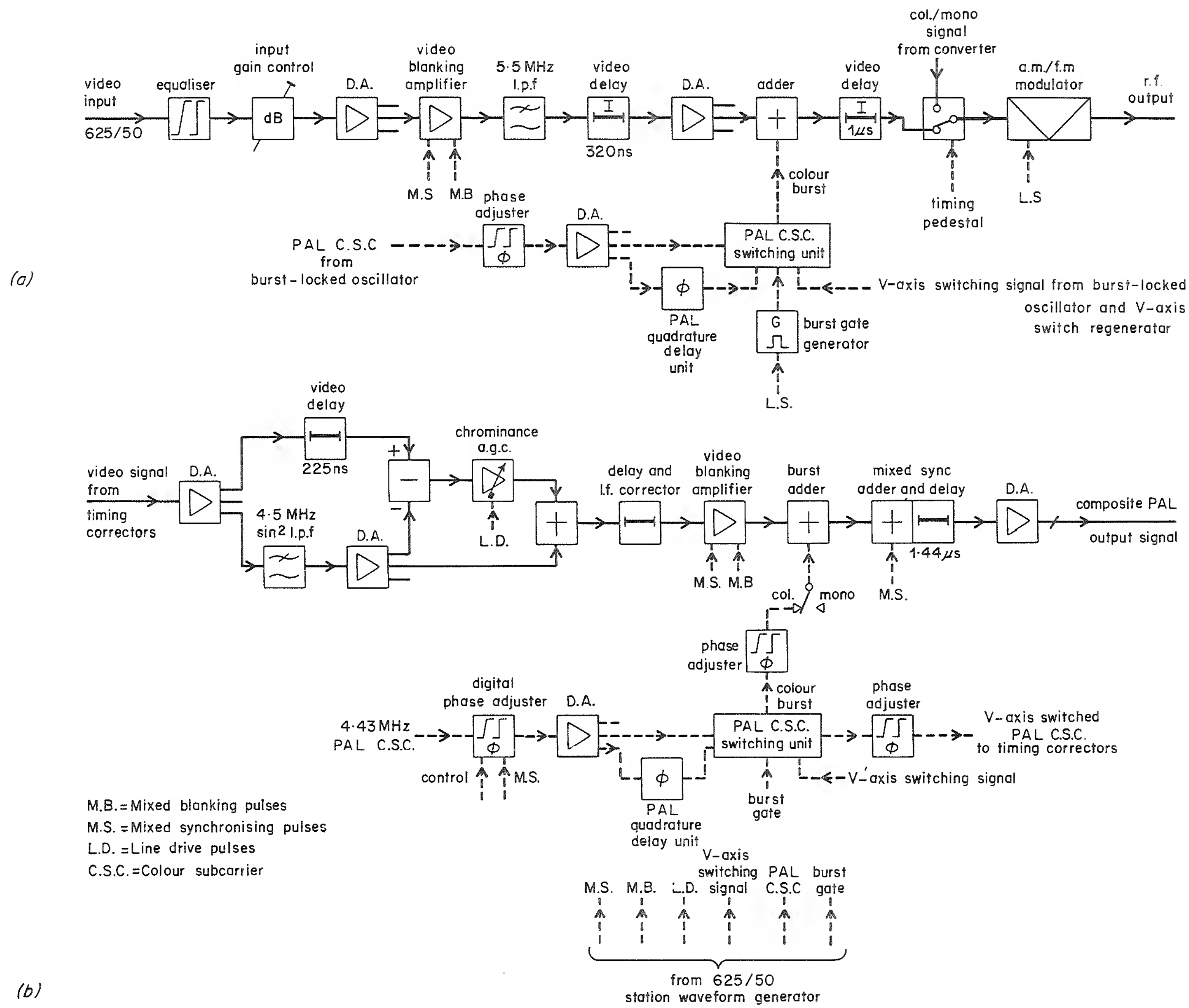


Fig. 8 - Synchroniser input and output signal processing arrangements
(*a*) Input signal path (*b*) Output signal path

TABLE 2

Performance of the C06/508 Field-Store Standards Converters*

Luminance signal-to-noise ratio (measured using 50% grey 'lift')

46·5 dB unweighted

Chrominance signal-to-noise ratio

37·5 dB (Comparative value only, measured using a special colour noise meter)

Luminance pulse and bar measurements

(*a*) Pulse k-rating

(Monochrome operation)	(Colour operation)
3%	4%

(*b*) Pulse-to-bar ratio

(Monochrome operation)	(Colour operation)
98%	97%

(*c*) Bar k-rating

2%

Chrominance-to-luminance gain inequality

This was measured using the so-called mini-bar. (In fact, the converters may be adjusted to give zero error in this case.)

−15·7%

Chrominance-to-luminance delay inequality

This was measured using the 10T chrominance pulse and again is a matter of adjustment; however, it was noted that the delays of the U and V channels may differ and that it would be better to allow the subcarrier phase to rotate to examine both channels.

−30 ns (chrominance lead)

(The need for a PAL swinging burst was avoided by disabling the V-axis switching in the input decoder and switching to simple PAL.)

Chrominance-to-luminance crosstalk

This is measured by observing the 'print' of the chrominance mini-bar upon its luminance pedestal and is expressed as the ratio of the peak-to-peak value of the print to picture signal level.

−0·85%

(A positive figure indicates that the value of the luminance pedestal was increased by the print.)

Differential gain distortion

This was measured using a 5-riser staircase signal with a low-level subcarrier on each step. The output was observed on a waveform monitor, which was sufficient for this application where noise prohibits more sophisticated and sensitive methods.

−5%

Differential phase distortion

The same staircase signal was used as above and the distortion observed on a vectorscope.

15°

Non-linearity

This was the so-called line-time non-linearity, and the staircase was used but without subcarrier.

6·7%

* Measured 'as found' without prior adjustment, except normal check of decoders and coders.

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